

METHOD FOR FORMING CUTTING ELEMENTS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Continuation of U.S. Patent Application No. 09/693,028, filed on October 20, 2000, which is a Divisional of U.S. Patent Application No. 09/103,824, filed on June 24, 1998 now issued as U.S. Patent No. 6,202,772.

BACKGROUND OF THE INVENTION

This invention relates to cutting elements for use in rock bits and more specifically to cutting elements which have a body with a canted cutting face on which is formed an ultra hard material cutting layer.

A cutting element, such as a shear cutter as shown in FIG. 1, typically has a cylindrical cemented tungsten carbide body 10. The cylindrical body has a cutting face forming the interface 12. An ultra hard material layer 14 is formed over the cutting face. The ultra hard material layer is typically polycrystalline diamond or polycrystalline cubic boron nitride. The ultra hard material layer typically has a planar or dome-shaped upper surface 16.

Shear cutters are generally mounted in preformed openings 22 on a bit body 18 at a rake angle 20 typically in the order of 10° - 20° (FIGS. 2 and 3). These openings have rear support walls 23. The cutters are brazed to the rear support walls. Typically, a 90° - 180° portion 24 of the cylindrical body outer surface is brazed to the rear support wall (FIG. 4). The brazed portions of the cutter body and rear support wall are sometimes referred to as the critical brazing area. During drilling, the portion of the cutting layer opposite the critical brazing area is subjected to high impact loads which often lead to crack formations on the cutting layer as well as to the delamination of the layer from the cutter body. Moreover, these high impact loads tend to speed up the wear of the cutting layer. The component 138 of the impact load which is normal to the earth formations is a severe load because it is reacting the weight of the bit body as well as the drill string. A majority of this load is reacted in shear along the interface between the cutting layer and the cutter body. This shear force promotes the delamination of the cutting layer from the cutter body.

To improve the fatigue, wear and impact lives of the ultra hard material layer as well as to improve the layer's delamination resistance, it is common to increase the thickness of the ultra hard material layer. However, an increase in the volume of ultra hard material results in an

1 increase in the magnitude of the residual stresses formed at the interface between the ultra hard material layer and the cutter body.

5 Because the overall length of the cutter has to remain constant for mounting in existing bits having the preformed openings 22, the increase in the thickness of the ultra hard material layer results in a decrease in the length of the cutter body. Consequently, the cutter body surface area available for brazing is reduced leading to an increased occurrence of cutter fall out during drilling. Cutter retention, is therefore, reduced when the ultra hard material layer thickness is increased.

10 Other efforts currently being made to improve the fatigue, wear lives as well as the delamination resistance of the cutting layer, include the optimization of the interface geometry between the cutting layer and the cutter body. By varying the geometry of this interface, as for example by making the interface non-uniform, the magnitude of the residual stresses formed on the interface due to the coefficient of thermal expansion mismatch between the ultra hard material layer and the cutter body is reduced.

15 Currently, there is a need for cutters having improved ultra hard material layer fatigue, wear and delamination characteristics without a reduction in cutter retention.

20 SUMMARY OF THE INVENTION

25 The present invention provides a cutting element and a method for making the same. The inventive cutting element has a cylindrical body being made from a hard material such as tungsten carbide, which has a canted end surface. The cutting element or cutter body length, therefore, decreases diametrically across the end surface. The canted end face of the cutter can be planar, curved both in a convex or concave fashion, may be stepped and may be non-uniform in cross-section. An ultra hard material layer, such as polycrystalline diamond or polycrystalline cubic boron nitride is formed over the canted surface. The upper surface of the ultra hard material layer is typically flat or dome-shaped. As such the thickness of the ultra hard material layer increases diametrically across the cutter end face. One or multiple transition layers may be incorporated between the ultra hard material layer and the cutter body.

30 When mounted on a bit body, the longer outer surface of the outer body and its adjacent portions are brazed to preformed openings on the bit body. The ultra hard material layer portion opposite the brazed area is the portion that makes contact with the earth formations during drilling.

1 The inventive cutter allows for an increased thickness of ultra hard material in the area
making contact with the earth formation and which is subject to the impact loads while at the
same time providing a relatively unchanged cutter body surface area which is brazed to the bit
body. In this regard, the delamination resistance of the ultra hard material layer as well as its
5 wear resistance and fatigue strength are increased, without effecting the retention of the cutter
within the bit. Moreover, by varying the thickness of the ultra hard material layer across the end
face, the volume of the ultra hard material may remain unchanged as compared to conventional
cutting elements thereby not increasing the residual stresses that may be formed at the interface
between the ultra hard material layer and the cutter body. In this regard the delamination
10 resistance of the ultra hard material layer is not decreased due to the increase in the layer
thickness making contact with the earth formations.

One way to form cutter bodies having canted interfaces is to first form a cylindrical work
piece having a diameter twice the diameter of the desired cutting element body and having a
convex protrusion. A cylindrical cutting element body is then cut preferably using EDM from
15 the work piece such that it is tangential to the work piece outer surface and to the work piece
central axis. A second body may be cut which is also tangential to the work piece outer surface
and which is tangential to the first cutting element body at the work piece central axis. Both
bodies may be cut simultaneously.

20 DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a conventional shear cutter.

FIG. 2 is a perspective view of a drag bit with mounted shear cutters.

25 FIG. 3 is a partial cross-sectional view of a shear cutter mounted on the bit body of
FIG. 2.

FIG. 4 is a partial top view of a shear cutter mounted on the bit body of FIG. 2.

FIG. 5A is a cross-sectional view of a shear cutter having a canted interface on top of
which is formed a cutting layer having a flat upper surface.

30 FIG. 5B is a cross-sectional view of the shear cutter having a canted interface on top of
which is formed a cutting layer having a dome-shaped upper surface.

FIG. 6 is a partial cross-sectional view depicting the cutter of FIG. 5A mounted on a bit
body.

35 FIG. 7A is a cross-sectional view of a cutter having a body having a stepped canted
interface.

FIG. 7B is a cross-sectional view of a cutter having a body having a canted interface on which are formed steps having a canted upper surface.

FIG. 7C is a cross-sectional view of a cutter having a body having a canted interface on which are formed steps having a curved upper surface.

FIG. 7D is a cross-sectional view of a cutter having a body having a canted interface on which are formed steps having a non-uniform upper surface.

FIG. 8A is a top view of a cutter body having a canted interface on which are formed zig-zag steps.

FIG. 8B is a top view of a cutter body having a canted interface on which are formed curved steps curving toward the lower edge of the canted face.

FIG. 8C is a top view of a cutter body having a canted interface on which are formed curved steps curving toward the higher edge of the canted face.

FIG. 8D is a top view of a cutter body having a canted interface on which are formed linear chord-wise steps.

FIG. 9A is a cross-sectional view of a cutter having a convex canted interface.

FIG. 9B is a cross-sectional view of a cutter having a concave canted interface.

FIG. 9C is a cross-sectional view of a cutter having a canted interface having two different radii of curvature.

FIGS. 9D, 9E and 9F are cross-sectional views of cutters having non-uniform canted interfaces.

FIG. 10A is a cross-sectional view of a cutter having a canted interface over part of which is formed an ultra hard material layer.

FIGS. 10B, 10C and 10D are cross-sectional views of cutters each having only a portion of its interface canted and an ultra hard material layer formed over the canted portion.

FIGS. 11A, 11B and 11C are top views of cutter partially canted interfaces.

FIG. 12A is a cross-sectional view of a cutter having a canted interface and having a transition layer formed over the canted interface.

FIG. 12B is a cross-sectional view of a cutter having a canted interface and having an encapsulated transition layer formed over the canted interface.

FIG. 12C is a cross-sectional view of a cutter having a partial canted interface and an encapsulated transition layer formed over the partially canted interface.

FIG. 13A is a cross-sectional view of a cylindrical work piece from which are cut forming cutter bodies having canted interfaces.

FIG. 13B is a top view of the work piece shown in FIG. 10A depicting the cuts for forming two cutter bodies.

1 DETAILED DESCRIPTION OF THE INVENTION

5 The cutting elements or cutters of the present invention have a body with a canted cutting face forming interface 112 (FIG. 5A). Stated differently, the interface is sloped. An ultra hard material layer 114 is formed over the canted interface. The upper surface 124 of the ultra hard material layer typically remains flat such that the thickness of the ultra hard material layer is minimum adjacent the highest point 128 on the interface and maximum adjacent the lowest point 126 on the canted face. Alternatively, the upper surface of the ultra hard material layer is dome-shaped (FIG. 5B). However, the radius of the dome-shaped surface is preferably relatively large such that the thickness of the ultra hard material layer is still maximum adjacent the lowest point 126 on the canted face. Preferably, the thinnest portion 133 of the ultra hard material layer should be in the order of 10-20% of the thickness of the thickest portion 134.

10 The overall length of the cutter of the present invention remains the same as that of a conventional cutter allowing for mounting into existing bit bodies. The cutter body outer surface longest length 130 as measured from the highest point 126 on the interface is the same or longer than the length of conventional cutter bodies. The length of the cutter along the lowest point of the interface is less than or equal to the length of conventional cutter bodies.

15 The cutters are mounted in the preformed openings 22 having a rear support wall 23 on the bit body 18 with the longest portion of the cutter outer surface 132 facing the rear support wall such that it becomes the surface of the cutter that is brazed to the bit body (FIG. 6). In other words, the longest cutter surface 132 is within the cutter critical braze area. Since the longest outer surface of the cutter is the same or longer than the outer surface of conventional cutters, the cutter brazing critical area remains almost the same as the brazing critical area of conventional cutters. However, in comparison to conventional cutters with increased thickness ultra hard material layers, the overall brazing area on the cutter body is increased.

20 When brazed on a bit, the thickest portion 134 of the ultra hard material cutting layer is positioned opposite the brazing critical area so as to make contact with the earth formations 136 during drilling. Consequently, this thickest portion of the cutting layer is the portion that is subjected to the impact loads during drilling.

25 Thus, the cutters of the present invention are optimized to have an ultra hard material cutting layer with an increased thickness at the location where the cutting layer impacts the earth formations while at the same time maintaining the cutters critical brazing surface area which is brazed to a bit body. As a result, the cutters of the present invention have an increased cutting layer delamination and wear resistance as well as fatigue life due to the increase in the thickness

1 of the ultra hard material that is subject to impact loads, without reducing the cutter retention life when brazed to a bit body.

5 The canted interface increases the offset of the interface from the severe impact loads 138 applied to the cutting layer during drilling. These loads are normal to the earth formation being drilled. As a result, the cant in the interface, reduces the portion of the impact load that is reacted in shear along the interface, thus reducing the shear stress along the interface. Consequently, the risk of cutting layer delamination is decreased.

10 Moreover, the canted interface allows for a distribution of the ultra hard material layer thickness without increasing the volume of the ultra hard material when compared to the volume of the ultra hard material in conventional cutters. As a result, the magnitude of the residual stresses formed on the interface between the cutter body and the ultra hard material layer do not increase by the increase in the thickness of the ultra hard material layer portion making contact with the earth formations.

15 In a first embodiment, the canted interface is planar as shown (FIG. 5A). In another embodiment the canted face is formed by a series of steps 140 along the interface (FIG. 7A). These steps ascend from a first point 126 to a second point 128 on the interface. The upper surface of these steps may be flat (FIG. 7A) or canted (i.e., sloped) themselves (FIG. 7B). The upper surface of the steps may also be curved (FIG. 7C). In further embodiments, the steps 140 may have upper surfaces 142 which are non-uniform (FIG. 7D). Of course, as is apparent to one skilled in the art, the steps themselves form a non-uniform face for interfacing with the cutting layer or with a transition layer. The steps may zig zag across the interface (FIG. 8A), or they may curve towards the lower edge 126 of the canted face (FIG. 8B) or toward the higher edge 128 of the canted face (FIG. 8C) forming horseshoe shapes or may be linear (FIG. 8D) across the canted interface.

25 As used herein, a uniform interface (or surface) is one that is flat or always curves in the same direction. This can be stated differently as an interface having the first derivative of slope always having the same sign. Thus, for example, a conventional polycrystalline diamond-coated convex insert for a rock bit has a uniform interface since the center of curvature of all portions of the interface is in or through the carbide substrate.

30 On the other hand, a non-uniform interface is defined as one where the first derivative of slope has changing sign. An example of a non-uniform interface is one that is wavy with alternating peaks and valleys. Other non-uniform interfaces may have dimples, bumps, ridges (straight or curved) or grooves, or other patterns of raised and lowered regions in relief.

1 The steps on the canted interface provide for an increased surface area for bonding of the
ultra hard material layer to the cutter body. The increased surface area also provides a reduction
in the shear stresses reacted along the interface thereby enhancing the delamination resistance of
the cutter. Moreover, the steps tend to reduce the effects of the coefficient thermal expansion
5 mismatch between the ultra hard material layer and the cutter body along the canted interface
thereby decreasing the residual stresses that are formed along the canted face, and as a result
increase the fatigue life and delamination resistance of the cutter.

10 In a further embodiment, the interface 112 may curve along the cant in a convex
(FIG. 9A) or concave (FIG. 9B) fashion. In one embodiment, the canted face has a larger radius
144 at the higher portion of the canted surface and a smaller radius 145 at the lower portion of
the canted face (FIG. 9C). Moreover, the canted interface itself may be non-uniform in cross
section for forming a non-uniform interface with a cutting layer (FIGS. 9D and 9E).
Furthermore, the non-uniformities may follow a curved cant as shown for example in FIG. 9F.
Again, the non-uniformities will reduce the residual stresses formed on the canted interface
15 thereby enhancing the delamination resistance of the cutting layer.

20 It has been discovered by the applicants that with conventional cutters mounted on a bit
body, microcracking occurs on the ultra hard material layer immediately adjacent the support
wall of the openings onto which the cutters are mounted. This microcracking eventually leads
to the chipping of the ultra hard material layer. It is believed that the microcracking is caused by
either or both of the following two reasons. First it is believed that the heat during brazing causes
the brazing flux to chemically react with the portion of the ultra hard material layer adjacent the
opening support wall causing "brazing poisoning" of the ultra hard material layer. This brazing
poisoning weakens the ultra hard material layer leading to the formation of microcracks.
Secondly, it is believed that at least a portion of the impact loads imparted on the cutting layer
25 are reacted at the rear support wall through the portion of the ultra hard material adjacent to the
rear support wall. These loads tend to cause chipping of the ultra hard material layer adjacent
the rear support wall.

30 To overcome this problem, in a further embodiments, the ultra hard material layer is
placed only over a portion 171 of the canted interface so as to not extend to the support wall of
the opening when mounted on a bit body (FIG. 10A). In some embodiments (FIGS. 10B, 10C
and 10D) only a portion 170 of the interface is canted and the ultra hard material is placed only
over the canted portion. The portion of the interface 172 that will be positioned adjacent to the
rear support wall remains uncanted. Preferably, when viewed in cross-section, about 1/3 of the
diameter of cutter interface is uncanted (i.e., only about 2/3 of the diameter is canted) as for
35 example shown in FIGS. 10A, 10B and 10C. When only a portion of the interface is canted,

1 the boundary between the canted and uncanted portions of the interface may be linear as shown in FIG. 11A or curved as shown, for example, in FIGS. 11B and 11C.

5 With these embodiments, since the ultra hard material layer is preferably only placed over the canted portion of the interface, it does not extend to the support wall of the bit opening when the cutter is mounted on a bit body. As such, all of these embodiments ensure that the ultra hard material layer of the cutter remains away from the braze area, i.e., the rear support wall, and thus is not prone to braze poisoning. Moreover, the impact loads will not be reacted through the portion of the ultra hard material layer closest to the support walls.

10 With any of these embodiments, a single (FIG. 11A) or multiple transition layers 115 may be formed between the canted face and the ultra hard material cutting layer. The transition layer(s) should preferably be made from a material having properties which after processing are intermediate between the ultra hard material layer and the cutter body. The transition layer or layers may also be encapsulated as shown in FIGS. 12B and 12C.

15 While there are many ways to form the body of cutter having a canted surface, one method calls for the formation of a cylindrical work piece 150 having a dome shaped (or convex) upper protrusion 152 (FIG. 13A). The work piece should have a diameter 154 twice the diameter of the desired cutter body. To form the cylindrical cutter body having the canted interface, preferably EDM is used to cut the cutter body tangential to the central axis 156 of the cylindrical work piece and tangential to the outer surface 158 of the cylindrical work piece. (FIG. 13B). In
20 a preferred embodiment, two cutter bodies may be cut simultaneously which are tangential along the work piece central axis 156 and which have their central axes 162 along a diameter 160 of the work piece as shown in FIG. 13B.